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Determination of Steam Consumption and Commercial Efficiency of Westinghouse Standard 25 H.P. Engine and Direct Connected Westinghouse 16 KW. Generator

W. R. Jones.
William le Kerr

June 9th 1899.

Jones & Kerr '99.
25 H.P. Westinghouse Engine.
98 A

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4 June '08. Ser. G. Engine . . 2; W.R.

This series of tests was made with a Westinghouse Standard Engine, number 7041 rated at 25 H.P., and a Westinghouse four pole generator number 50429 rated at 15.6 K.W - 125 Volts.

The object of this series of tests was to determine the steam consumption per I.H.P. hour, and per K.W. hour, the commercial efficiency, that is the ratio of the I.H.P. to the electrical horse power delivered to the external circuit; and also to determine whether the speed and voltage remain constant under varying loads.

The engine and dynamo are part of the "Light heat and power plant of the University

of Pennsylvania. The engine and dynamo occupy a space 3' 2½" by 6' 9½" and are mounted on a common bed-plate. The base of the engine is 2' by 3' and that of the dynamo 3' 1" by 2' 11". The combination has been running for about two years, carrying the day load and running about eighteen hours out of the twenty four. The engine is a double cylinder engine single acting, the cranks being set 180° apart. The cylinders are 7½" diameter, the stroke is 7" and the connecting rods 18½". There are no piston rods, the connecting rod being fastened direct to the piston. One distinguishing feature of the Westinghouse Standard Engine is that the center of

the shaft is not on the center lines of the cylinders, but is set over an amount which in this particular engine is $1\frac{3}{4}$". The cranks and governor are entirely encased and run in a mixture of water and oil. The admission of steam to the two cylinders is controlled by a piston valve placed between the two cylinders at the bottom, but inclined so as to be to the rear of the cylinders at the top. The motion of the valve is regulated by an automatic wheel governor. In the upper cover of each cylinder is a release valve of a design peculiar to the Westinghouse Company. These valves will be more fully described in connection with

the indicator rig.

The generator is direct connected to the engine by means of a flexible spring coupling. It is a compound wound, four pole, slow speed dynamo rated to run at 375 r.p.m. and maintain 125 volts at the terminals. It is now run at a slightly slower speed so as to maintain 110 volts and is over compounded. The bearings are of the standard ring self oiling type. The cores of the field are laminated wrought iron, the frame being cast around the cores. The shunt and series windings which are seperate, that is not one over the other, are held on by means of gun-metal plates. The armature is drum

wound and is of the slotted type. There are four rectangular conductors in each slot. The armature is parallel connected. There are four sets of carbon brushes placed 90° apart, there being two brushes in each set. There are three wires leading from the machine namely; the two main leads and the shunt which connects to the positive pole of the switch through the rheostat. The machine end is connected to the negative brush. The connections are such that the ammeter does not record the current passing through the shunt winding, see figure 4 page 76. There is no equalizer and this machine can not be run in parallel with

the other machines in the station.

The engine had not been indicated before, and it was necessary to make an indicator rig, see figure 1. page 73. The motion of the indicator barrels was made one half the stroke of the engine. This made the cards 3½" long. The only place where we could get a motion similar to that of the pistons was on the end of the shaft. That farthest from the generator was clear and was therefore utilized. To get the exact motion of the pistons it was necessary to represent the pistons by blocks sliding in guides. The blocks are connected by links to a pin on the end of the shaft. The shaft

is only 2" in diameter. This made it necessary to make a cap to fit on the end of the shaft. In this cap is a pin 1 3/4" from the center of the shaft. The connecting rods of the engine are 18 1/2" long, and the links of the indicator rig were made 9 1/4" long. The blocks are set so that the lines of travel of the pins on them are 7/8" from the center of the shaft. The dimensions of the indicator rig are thus one half those of the engine. It would be impossible to use two pins set 180° apart on the same cap but this is overcome by using one pin and placing one block below the shaft and set over from the center the same amount but in the opposite

direction. This block is called number 2 in the figure and corresponds to the piston nearer the engine end of the shaft. Block no 1. corresponds to the piston away from the engine end of the shaft. This notation is retained throughout; the cards when taken were numbered no. 1 or no. 2 according to which cylinder they represent. No. 1 is the cylinder at the dynamo end of the shaft, and no. 2 is the cylinder at the engine end of the shaft. The position of the pin on the cap corresponds to the crank pin connected to piston no. 1. The indicator rig for no 1. is an exact reproduction as to position and relative dimensions of the cor-

responding engine. With no. 2 the block is below the shaft while the piston is above. We have next to prove that blocks no. 2 has a motion corresponding to piston no. 2. The position of the crank pin corresponding to piston no. 2 is 180° from that of the pin on the cap. If the center of the shaft were on the center line of the piston this would merely reverse the position of the block, that is the block would be at the lower end of its travel when the piston was at the upper end. With the position shown in the fegure, piston no. 2 has moved up a distance, which for an infinite connecting rod would be proportional to the versedsine of the angle

through which the crank has moved from the vertical position. Neglecting for the moment the effect of the angularity of the link, block no. 2 has moved down a distance which is proportional to the versedsine of the angle through which the pin on the cap has moved from the vertical position. Since the pin on the cap and the crank are 180° apart the distances are proportional to versedsines of equal angles. In both cases the crank pin is on the opposite side of the shaft from the outer line of travel. The connecting rod and link bear the same ratio to their respective cranks, and therefore the angularity is the same in both cases.

Therefore the motion of the block and piston are similar at all points. The motion of the block however is in the opposite direction from that of the piston and one half as great since the cranks have the ratio of one to two.

Having the motion of the blocks similar to that of the pistons, the next step was to communicate this motion to the indicators. The indicators were placed on the cylinder covers, as described later see page 13. The guides for the blocks were fastened to a board stiffened by strips along the sides and across the ends. This board was clamped at the bottom by a piece of wood wedged between the engine base and

that of the engine nearest it. At the top, the board is held in a vertical position by wrought iron straps clamped under the nuts that hold the cover on cylinder no. 2. A hole was cut near the center of the board to allow the cap on the end of the shaft to project through.

The method of attaching the indicators was as follows; the relief valves, see fig. 2 page 74, on the cylinder covers were removed. In their place two close nipples of 1½" wrought iron pipe, were screwed in. The threaded portion of the relief valves is 1½" in diameter. To the nipples two tees 1½" × ½" × 1½" were screwed so as to bring the ½" hole at the top. Into the ½" hole the in-

dicator cocks were screwed and the relief valves into the 1½" branch, their position being horizontal now instead of vertical. The relief valves were pointed toward the steam distributing valve, that is away from a person taking cards. The indicators were thus brought vertical by over the center of the cylinder covers and the cords about 8" from the covers.

From the first we had trouble with the indicators. The first scheme tried was to have braided steel wires run from the pins on the blocks up over pulleys on the upper end of the supporting board to springs fastened to a vertical arm. This arm was made by bending a piece of wrought iron at

right angles. A hole was drilled in one arm and the piece slipped over one of the cover bolts on cylinder no. 1 and clamped with the nut. The indicator cords were fastened to wire eyes bound to the braided wire. The scheme for connecting and disconnecting the indicators was to have the indicator cord pass through the eye but provided with a cross piece against which the wire eye pressed and worked the indicator. To disconnect the indicator, the indicator cord was pulled out so that the wire eye did not strike the cross piece. There were several faults with this arrangement. To work quickly and keep the braided wire tight the springs had to be fairly strong.

This put considerable tension in the wire and caused it to cut through at the point where it ran over the pulleys. We next replaced the portion of the wire that ran over the pulleys by indicator cord. This broke also. We found that the wire eye and cross pieces were too complicated, and the cords got tangled. We next fastened the indicator cord firmly to the wire eyes and made a loop at the far end of the braided wire. The scheme was to slip this loop over the pins on the blocks while running. This arrangement did not work at all. The wire broke after one or two revolutions or in getting the loop over the pin. We next abandoned the idea of

an auxillary spring and replaced the wire by indicator cord. The indicators were connected as before by slipping a loop over the pins on the blocks, but this was hard to do and required considerable time. The next step was to tie a short piece of indicator cord to the pins on the blocks. To the other end of this cord was tied a wire hook. The method of connecting the indicators was as follows: a loop was made in the end of the cords leading from the indicators. While the engine is running the wire hook can be raised the length of the cord tied to the block, above the lowest position of the block. The cords from the indicators should

be of such a length that when the indicator barrels are pulled all the way out, the loops can just be slipped over the hooks tied to the blocks. Then upon releasing the cords the spring under the indicator barrels, draws them back as the block goes up. The springs of the indicator barrels did not act quick enough. Unless tightened up considerably the barrels would strike at both ends of the stroke. When the springs were tightened as much as possible the barrels would stick. At the spead at which the engine ran, the effect of the inertia of the barrels was considerable. By removing the barrels the frame would run very well where with

the barrels on, the indicator would not work at all. The indicators used were "American Thompson Improved Indicators. They were paired that is one was a right and the other a left hand indicator. The left hand indicator no. 3071 was placed on cylinder no. 2. We could not get this adjusted so as to work properly and was replaced by a right hand indicator of the same make. We could then make the indicators run but the vibration of the strings was considerable, the weight of the connecting hooks adding considerably to this. We got cards as much as 5" long in place of 3½", which was the travel of the blocks. We next placed a guide between the pulleys

and the indicators. This consisted of an upright board with wire eyes through which the cord ran. Then between the pulleys and the blocks we fastened four horizontal pieces of wood with holes in them through which the cords ran. The cord to block no. 2 ran through all four guides while that to no. 1 ran through one only. This reduced the vibration considerably and we got cards that overran from $\frac{1}{10}$" to $\frac{2}{10}$"; part of this is due to the stretch of the cord, part to vibration, part to inertia, and part to the springs of the indicators not having a short enough period of vibration. There did not appear to be any way of reducing this stretch so we

used the indicator rig this way.

To get the water consumption we required a condenser. There was a condenser near the engine which was rated at 1000 lbs per hour. The condenser was designed in the department of dynamical engineering of the University of Pennsylvania. A drawing giving the various dimensions is kept on file although not catalogued. The engine exhausted vertically downward. A short pipe came out horizontally and the bend was made by means of an angle valve. We replaced this valve by a tee (see fig 3 page 75) and below the tee placed a straight away valve. From the tee we ran a pipe vertically upward

and used the angle valve to turn to a horizontal direction. The remainder of the piping is shown in the figure. The arrangement is such that by closing the angle valve and opening the straight away valve, the engine exhausts as before while by opening the angle and closing the straight away valve, the engine exhausts through the condenser. The condenser is used in connection with the Weston engine belonging to the Mechanical Laboratory. Connection was made by a tee and a valve put in as shown in the figure. The steam when condensed was weighed in an iron tank placed on platform scales.

A steam gauge was connected to the steam pipe just above the engine by means of a syphon. A gauge was similarly attached to the condenser to detect any back pressure. The quality of the steam was determined by means of a "Carpenter Improved Separating Calorimeter". The pipe collecting the sample of steam extends nearly across the steam pipe, and has a number of small holes drilled in it.

In conducting a test the work was divided into two parts. One person attended to weighing the condensed steam and taking the cards, while the other took the general readings. After each test the places were exchan-

ed. The tests lasted two hours each and readings were taken every ten minutes.

The method of weighing the water was such that the exact amount of steam condensed in ten minutes was determined. To do this the method used was as follows: before the test started the discharge pipe from the condenser is placed with the outlet below the lowest point of the condenser see fig 3. page 75. This allows the water to run out as fast as the steam is condensed. The weight of the iron tank and whatever water may be in it is noted. At the instant the test starts the discharge pipe is swung over so as to discharge into the tank. About

fifteen seconds before the end of the ten minute interval the discharge pipe is allowed to drain into a bucket. Call this bucket number one. At the end of the interval the pipe is moved over to a second bucket. Call this bucket number two. These buckets are below the lowest point of the condenser so that at the end of the interval all the condensed steam has been drained out of the condenser. The water in bucket no. 1 belongs to the interval just passed and is poured into the iron tanks. The weight is then taken and the difference between this and the preceding weight, gives the amount that has been condensed in ten min-

utes. Meanwhile the water has been collecting in bucket no. 2. This belongs to the next period and is poured into the iron tank, and at the end of the interval the process is repeated. The condenser was tested for leakage, when the engine was exhausting the other way, by turning on the fed water. The discharge pipe was lowered and after considerable time as no water leaked through, the leakage was taken as zero.

The arrangement for taking cards has been described. It was found necessary for the person taking the general readings to connect the indicators while the other took the cards.

In taking the general read-

ings the calorimeter was read first because it is necessary to determine the amount of water collected in ten minutes. The gauge connected to the calorimeter is calibrated in pounds pressure per square inch and also to read direct the number of pounds of steam that is discharged through the orifice of the instrument in ten minutes. The pressure scale reads to five pounds but the pointer shakes so that it was difficult to read even to five pounds. Again when tested the gauge was found to be in error twelve pounds at the portion of the scale used. The steam gauge connected to the steam pipe is not far from the calorimeter. It could be read to

one half a pound and is nearly correct. We therefore took the mean of the steam gauge readings and found the corresponding discharge on the calorimeter gauge. The number of pounds of water collected divided by the sum of the number of pounds collected and the number discharged in the same interval gives the percentage of moisture in the steam.

The arrangement of the instruments and connections for obtaining the data for calculating the electrical output of the machine are shown in figure 4 page 76. A Weston volt-meter, no 88, was placed across the terminals of the machine while the am-meter

on the board was read to get the amperes delivered to the external circuit. The switch board ammeter is a Queen-Wirt instrument and belongs to the class of gravity control instruments. An Acme volt-meter, no. 29, was placed across the terminals of the shunt while Weston am-meter, no. 26, was put in series with the shunt. These instruments were read with the intention of seperating the losses but this was not done owing to the fact that the indicators did not give accurate results as explained on page 34. At the time of making the heavy load test, May 31-'99, a Weston am-meter, makers number 2023, was put in the main circuit. After the

test various loads were put on the dynamo and simultaneous readings of the Weston and switch board am-meters taken. The Weston am-meter had recently been calibrated by Messers J. R. Brown and C. Day in connection with their thesis. They kindly permitted us to use their calibration curve and the reading of the Queen-Wirt am-meter was corrected as follows: taking the reading of the Weston corresponding to a certain reading of the Queen-Wirt we obtained from the calibration curve the true number of amperes corresponding for the Weston and at the same time for the Queen-Wirt. We next plotted a curve, see page 72, with the readings of the

Amer. Writ. as abscissae and the true number of amperes corresponding as ordinates. A calibration curve of Weston voltmeter, no. 88, was also loaned us by Messrs Brown and Day. The steam gauge used was a Bourdon steam gauge no. 207978, made by the American Steam Gauge Co. Boston. This was calibrated by means of a Crosby gauge tester. The readings are given on page 37. The readings were plotted as a curve, see page 39, with gauge readings as ordinates and true pressures as determined by the gauge tester, as abscissae. The platform scales were tested by weighing a known weight and found to be correct. The springs of the indica-

tors were calibrated while hot. The indicators and gauge no. 207978 were attached to a piece of 2" pipe closed at the ends by caps into which ¾" pipes are screwed. Live steam enters through the upper pipe while the other is open to the air. There is a valve above and one below the 2" pipe. By adjusting these valves the pressure in the 2" pipe is made to gradually rise from atmospheric to boiler pressure, and then gradually fall to atmospheric pressure again. Every ten pounds as indicated by the gauge a line is drawn on the paper on the indicator barrel both as the pressure rises and as it falls. As the pressure rises the barrel is

pulled all the way out while as the pressure falls the lines are made shorter to distinguish them. The values of the springs are calculated at each point and the mean taken as the mean value of one inch ordinate on the cards. The springs are supposed to be fifty pounds per inch ordinate. We measured the ordinates of the calibration cards ascending and descending in fiftieths of an inch and took the mean. If the springs were correct this would be numerically the same as the pounds per square inch. From the calibration of the gauge we have the true pressure per square inch. Then multiplying the true pressure by fifty and dividing by the mean

ordinate of the calibration card, in fiftieth of an inch; gives the number of pounds per square inch represented by one inch ordinate at this particular pressure. The mean of these results is taken as the mean value of one inch ordinate of the cards taken. The same indicators and springs were used each time on the respective cylinders.

The readings taken during the tests are given on pages 37 to 64. The results calculated from the readings are given on pages 66 to 72. A curve showing the water per kilo-watt hour is given opposite page 72.

In conclusion we would say that

the values of the commercial efficiencies come so high that it is evident that there is some large error in the work. The fact that places were exchanged after each test renders it improbable that there was a personal error in reading the instruments. The only place where an error could occur to effect the results to this extent is in the indicators. We attribute the trouble to the springs of the indicator barrels which could not be made to act quick enough without binding. We believe that if the length of the cards were made less than 3½" less trouble would be experienced. Even if no allowance is made for the stretch the efficiency is still too high. The variations in the areas of the cards make it appear probable that the indicators did not record properly what took place in the cylinders.

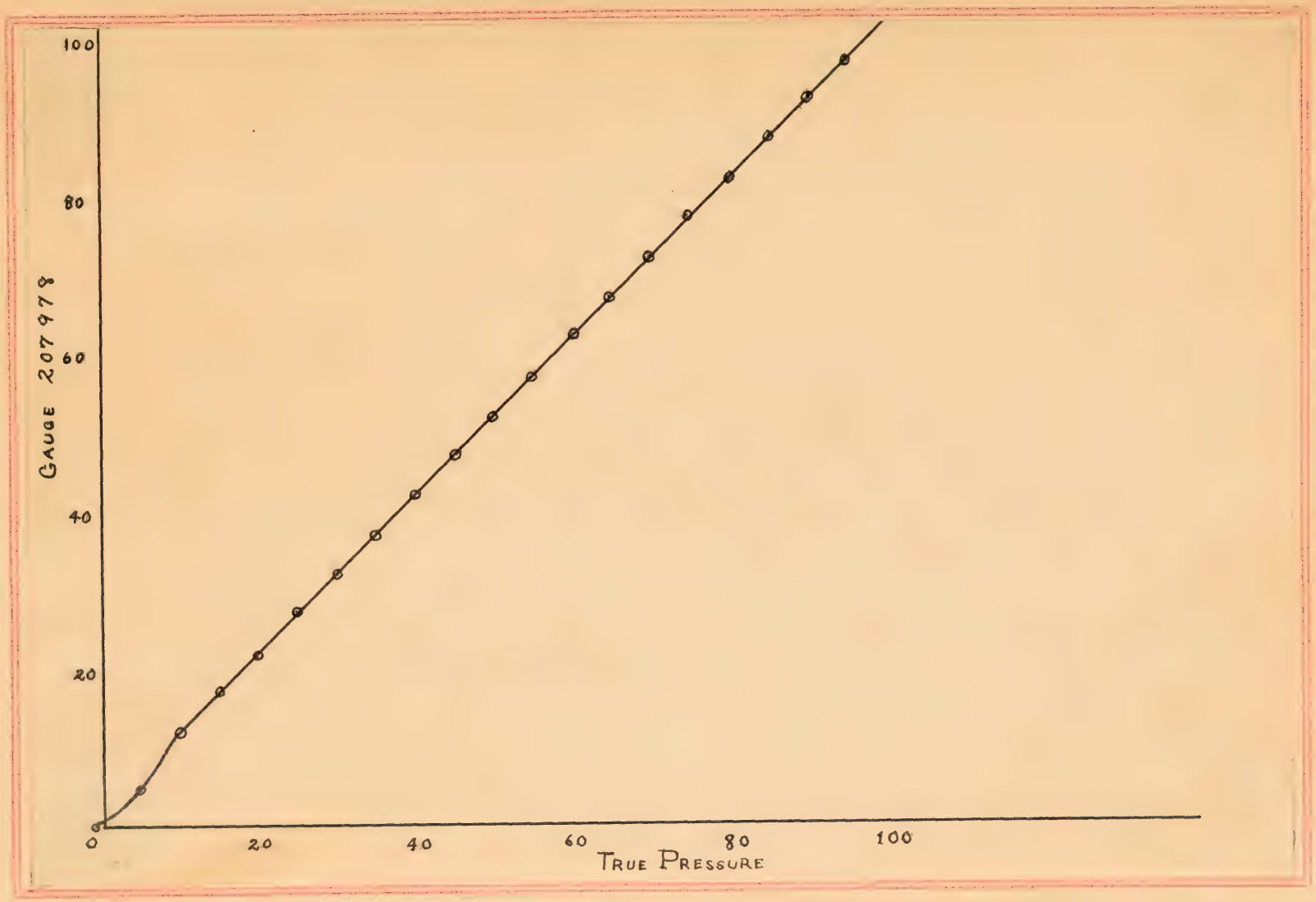
W.R.J. 6-4-98

Readings.

Calibration of.
Bourdon Steam Gauge
No. 207975.

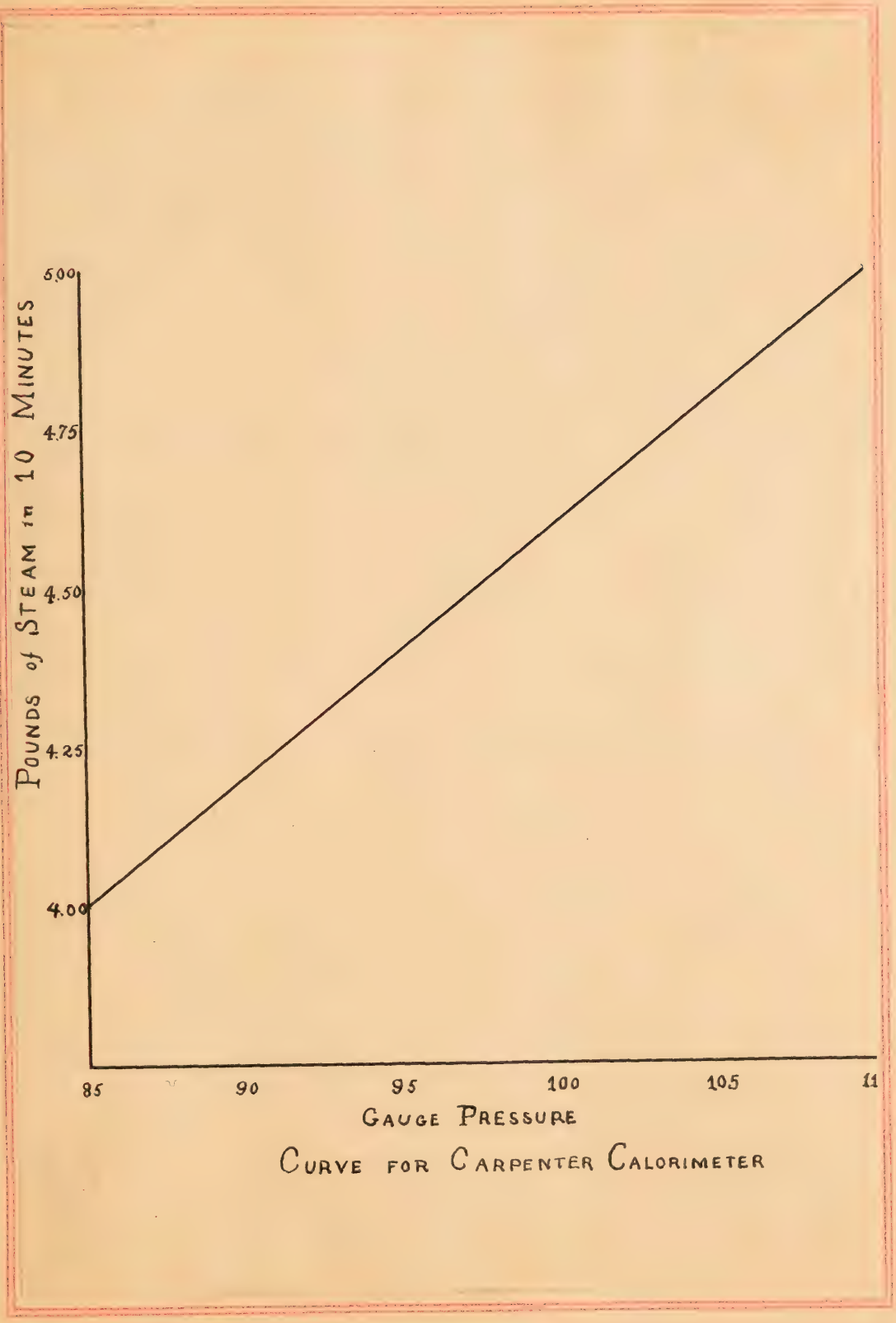
Gauge Tester lbs. per □"	Gauge going up lbs per □"	Gauge going down lbs. per □"	Mean. lbs per □"
5.	4.50	5.00	4.75
10.	11.50	12.50	12.00
15.	17.00	18.00	17.50
20.	21.75	22.25	22.00
25.	27.00	28.00	27.50
30.	32.00	33.00	32.50
35.	37.00	38.00	37.50
40.	41.75	42.75	42.25
45.	47.00	47.50	47.25
50.	52.00	52.50	52.25
55.	57.00	58.00	57.50
60.	62.00	63.00	62.50
65.	67.00	67.50	67.25
70.	72.00	73.00	72.50
75.	77.00	78.00	77.50

80.	81.50	83.00	82.25
85.	87.00	88.00	87.50
90.	92.00	93.00	92.50
95.	97.00	97.50	97.25
100.	102.50	103.00	102.75
105.	107.00	108.00	107.50


100
80
60
40
20
0
20
40
60
80
100
GAUGE 207978
TRUE PRESSURE

Calibration of Calorimeter Gauge.

Gauge Tester lbs. per □"	Gauge going up. lbs. per □"	Gauge going Down. lbs. per □"
85.	97.	97.
90.	102.	102.
95.	107.	107.
100.	112.	112.
105.	116.	116.
110.	121.	121.
115.	126.	126.
120.	131.	131.



Curve for Carpenter Calorimeter

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Calibration of Indicator Spring # 3382.

Ordinate. Up. lbs. per □"	Ordinate Down lbs. per □"	Mean ordinate lbs. per □"	Gauge lbs. per □	True Press lbs per □"	Spring Value.
0.	0.	0.	0.	0.	—
7.25	9.00	8.12	10.	8.00	49.26
18.00	18.00	18.00	20.	18.00	60.00
27.00	29.00	28.00	30.	27.50	49.00
37.00	39.50	38.25	40.	37.00	48.39
47.00	48.50	47.75	50.	47.50	49.74
56.50	60.00	58.25	60.	57.50	49.34
67.00	70.00	68.50	70.	68.00	49.63
77.00	80.00	78.50	80.	78.00	49.68
87.50	90.00	88.75	90.	88.00	49.51

Mean value of one inch ordinate on cards

= 49.4 lbs. per □"

Calibration of Indicator Spring #3071.

Ordinate Up lbs. per □"	Ordinate Down lbs. per □"	Mean Ordinate lbs. per □"	Gauge lbs per □"	True Pressure lbs. per □"	Spring Value.
0.	0.	0.	0.	0.	—
7.00	7.00	7.00	10.	8.0	57.14
16.00	17.00	16.50	20.	18.0	54.54
24.50	28.50	26.50	30.	27.5	51.85
35.00	38.50	36.75	40.	37.0	50.44
45.00	48.00	46.50	50.	47.5	51.08
54.50	58.00	56.25	60.	57.5	51.11
64.00	68.50	66.25	70.	68.0	51.32
74.50	78.00	76.25	80.	78.0	51.14
84.25	86.50	85.38	90.	88.0	51.53

Calibration of Queen-Wirt Amp-Meter. # 1973.

Weston. amperes.	True amperes.	Queen-Wirt. amperes.
-.5	0.	-3.0
21.0	21.0	24.0
50.0	49.0	50.0
79.0	77.0	77.0
101.0	97.5	99.0
122.0	118.0	119.0
135.0	130.0	130.5
145.0	140.0	141.0

General Readings

Test no. 1. May 11th 1899.

Time	Calorimeter Gauge lbs per □"	Calorimeter lbs. water evaporated	Steam Gauge lbs per □"	Vacuum Gauge lbs per □"	Shunt Ammeter	Shunt Voltmeter	Terminal Voltmeter	Board Ammeter	Exc. Shunt Volt-meter	Revolutions per minute	Time after reading
P.M.											P.M.
3-22	92.5	.015	90.5	0	4.10	75.0	110.0	32.0	—	368.0	3-25
3-30	95.0	.035	92.5	0	4.10	78.0	109.5	32.0	—	370.0	3-33
3-40	92.5	.055	90.0	0	4.30	79.5	111.0	33.0	82.0	367.0	3-45
3-50	95.0	.082	93.5	0	4.30	80.0	112.0	33.75	82.0	371.0	3-57
4-0	97.5	.105	95.0	0	4.16	78.0	111.0	33.0	82.0	370.0	4-04
4-10	95.0	.130	92.5	0	4.20	79.5	110.9	33.5	83.0	369.0	4-15
4-20	95.0	.155	92.5	0	4.20	80.0	111.0	32.5	83.5	368.5	4-26
4-30	95.0	.177	92.5	0	4.30	82.0	111.5	33.0	83.5	367.5	4-35
4-40	95.0	.200	92.0	0	4.10	79.0	109.9	32.25	83.5	367.5	4-45
4-50	92.5	.207	90.5	0	4.20	81.0	110.0	32.75	83.0	367.5	4-57
4-51	—	.055	—	—	—	—	—	—	—	—	—
5-0	95.0	.070	93.5	0	4.23	82.0	111.0	33.0	84.0	367.75	5-05
5-10	95.0	.085	93.0	0	4.19	81.5	110.6	33.0	84.0	367.5	5-15
5-20	95.0	.102	94.0	0	4.20	81.5	111.5	33.0	84.0	367.5	5-25
	1230.0		1202.0	0			1439.9	426.75		4418.0	
	94.62		92.46	0			110.76	32.83		368.4	

Readings- Water.

Test No. 1. May 11th 1899.

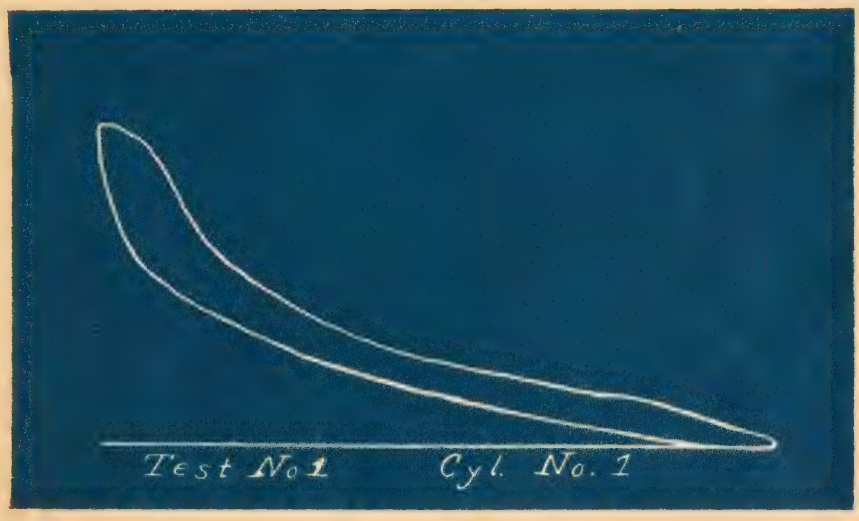
Time	Weight lbs	Weight Empty lbs.	Net Wt of condensed Steam lbs.
P.M.			
3 hrs 20 min	129.0	129.0	0.
3 " 30 "	196.0		
3 " 40 "	275.5		
3 " 50 "	355.0		
4 " 00 "	430.0		
4 " 10 "	514.0		
4 " 20 "	591.5	129.0	462.5
4 " 20 "	149.0	149.0	0.
4 " 30 "	226.0		
4 " 40 "	303.0		
4 " 50 "	380.0		
5 " 00 "	457.0		
5 " 10 "	537.0		
5 " 20 "	613.0	149.0	464.0

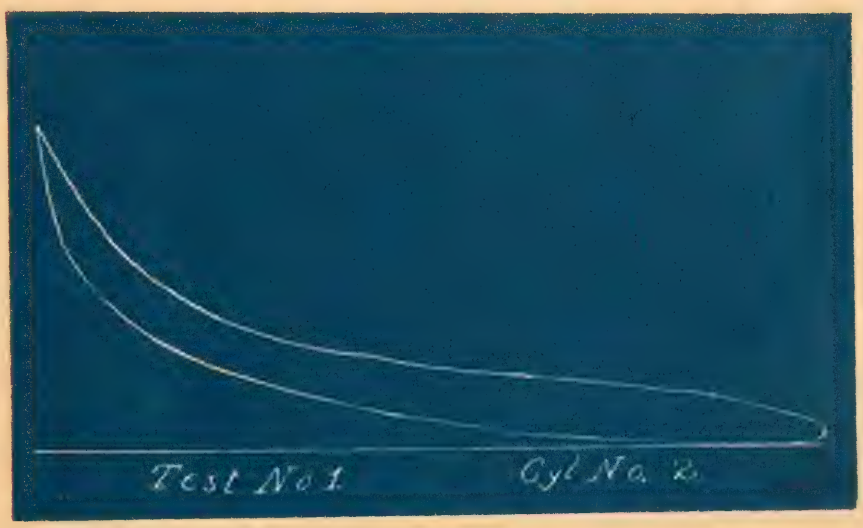
463.25 lbs steam per hour.

Sample Cards

from

Test No. 1. May 11th 1899.





Cards.

Test No. 1. May 11th 1899.

Time	← Cylinder No 1 Area □"	Length. Inches. →	← Cylinder No. 2 Area. □"	Length. Inches. →
3-20	0.860	3.66	1.215	3.90
3-30	0.845	3.67	1.215	4.00
3.40	0.775	3.68	1.235	4.03
3-50	0.865	3.65	1.275	3.95
4-00	0.810	3.70	1.140	4.10
4-10	0.845	3.64	1.160	4.05
4-20	0.830	3.68	1.160	4.02
4-30	0.780	3.55	1.190	4.06
4-40	0.860	3.73	1.180	4.02
4-50	0.850	3.68	1.165	4.00
5-00	0.815	3.70	1.160	4.14
5-10	0.800	3.66	1.135	4.14
5-20	0.900	3.68	1.040	4.10
	1.0805	47.68	15.270	52.51
	0.831	3.66	1.175	4.04

Mean ordinate No 1. 0.224" No 2. 0.2908"

General Readings

Test No. 2. May 15th 1899.

Time.	Calorimeter Gauge "Hg. plus □"	Calorimeter lbs water separated.	Steam Gauge lbs. per □"	Vacuum Gauge lbs per □"	Shunt Ammeter.	Shunt Voltmeter	Temp. Shunt Voltmeter	Terminal Voltmeter	Board Ammeter	Revolutions per minute	Time after readings
P.M.											
3-10	—	—	91.5	0	4.20	82.5	80.	110.0	65.	360	3-16
3-20	85	.020	87.0	0	4.30	86.0	80.	112.0	65.	360	3.25
3-30	88	.065	90.0	0	4.30	85.0	80.	111.0	73.	360	3.34
3-40	88	.110	90.0	0	4.20	84.0	80.	111.0	74.	360	3.49
3-50	88	.145	90.0	0	4.20	84.0	80.	110.0	77.	362	3.56
4-00	88	.180 .050	90.0	0	4.10	82.5	80.	109.0	54.	365	4.05
4-10	102	.065	104.0	0	4.35	87.0	81.	113.0	58.	365	4.15
4-20	96	.086	97.0	0	4.25	85.0	81.	111.0	60.	364	4.24
4-30	98	.100	99.0	0	4.25	86.0	81.	112.0	61.	364	4.35
4-40	94	.122	102.0	0	4.30	87.0	80.	112.5	62.	363	4.45
4-50	98	.140	99.0	0	4.40	89.0	80.	113.0	62.	364	4.54
5-00	104	.170 .060	106.0	0	4.30	87.0	81.	112.0	62.	364	5.04
5-10	96	.080	97.0	0	4.40	89.0	80.	113.0	60.	364	5.14
	1125		1243.5					1449.5		4715	
	93.75		95.58					111.5		362.7	

Readings - Water.

Test No. 2. May 15th 99

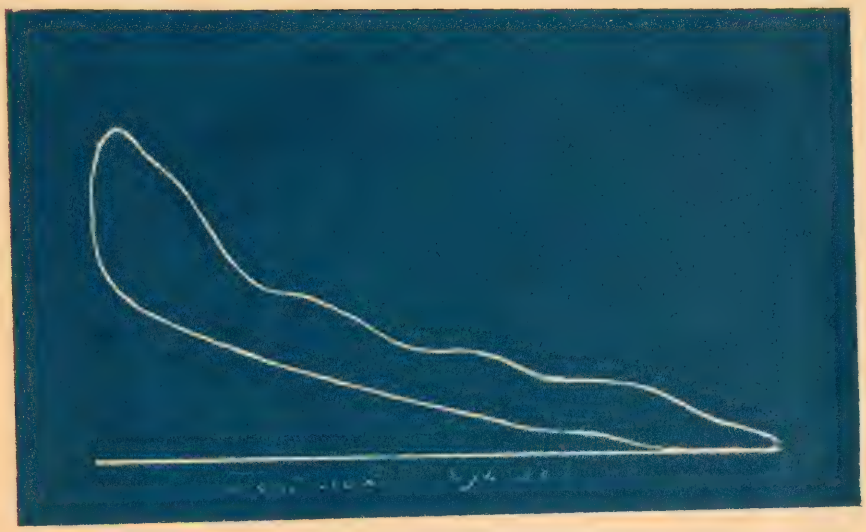
Time	Weight lbs	Weight Empty lbs	Net. Wt. of condensed Steam lbs.
P.M.			
3 hrs 10 min	137.50	137.50	0
3 - 20	239.25		
3 - 30	344.25		
3 - 40	453.50		
3 - 50	565.50	137.50	428.0
3 - 53	154.00	154.0	0
4 - 00	243.25		
4 10	347.75		
4 - 20	447.00		
4 - 30	547.00	154.0	393.0
4 33	130.00		
4 - 40	251.75		
4 - 50	353.00		
5 - 00	457.00		
5 - 10	559.00	150.0	409.0

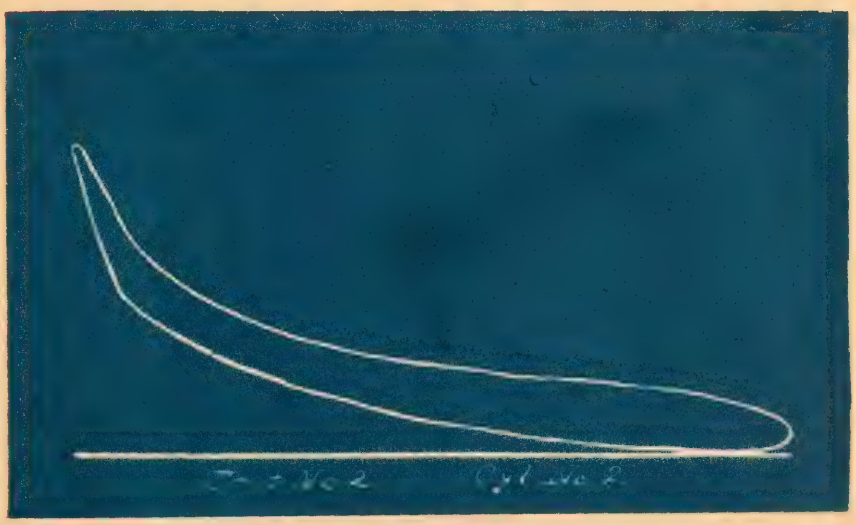
615.0 lbs steam condensed per hr.

Sample Cards

from

Test No. 2. May 15th 1877





Cards.

Test No. 2. May 15th. 1879.

Time	← Cylinder No. 1 → Area □"	Length Inches	← Cylinder No 2. → Area □"	Length Inches.
3 hrs 10 mns.	1.365	3.59	1.150	3.70
3 " 20 "	1.365	3.61	1.265	3.74
3 " 30 "	1.525	3.58	1.435	3.70
3 " 40 "	1.530	3.60	1.370	3.70
3 " 50 "	1.435	3.62	1.255	3.81
4 " 00 "	1.160	3.65	0.915	3.82
4 " 10 "	1.270	3.52	0.960	3.82
4 " 20 "	1.290	3.60	0.905	3.82
4 " 30 "	1.280	3.63	0.990	3.90
4 " 40 "	1.325	3.60	0.955	3.82
4 " 50 "	1.360	3.61	1.045	3.80
5 " 00 "	1.350	3.58	1.020	3.87
5 " 10 "	1.350	3.60	1.020	3.88
	17.605	46.79	14.285	49.37
	1.3542	3.599	1.0988	3.798

Mean ordinate No 1. 0.376" No. 2. 0.289

General Readings

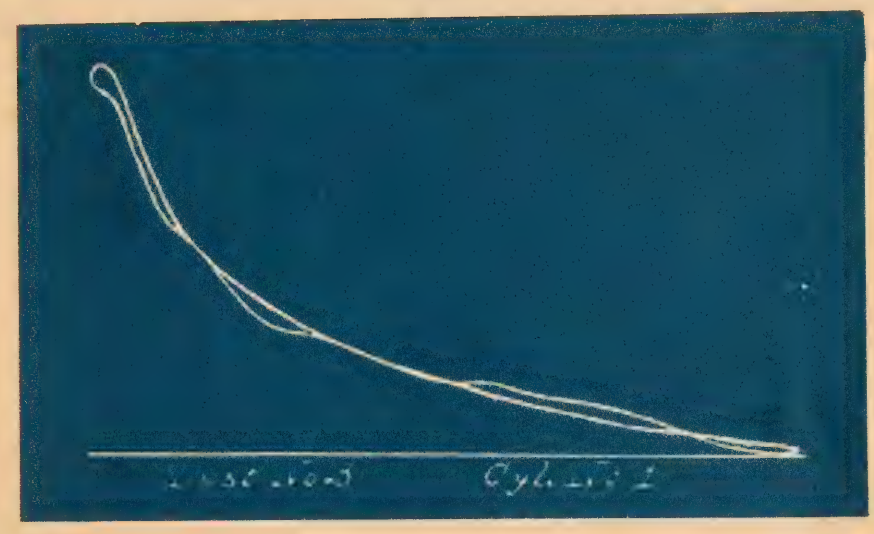
Test No. 3. May 15th 1899.

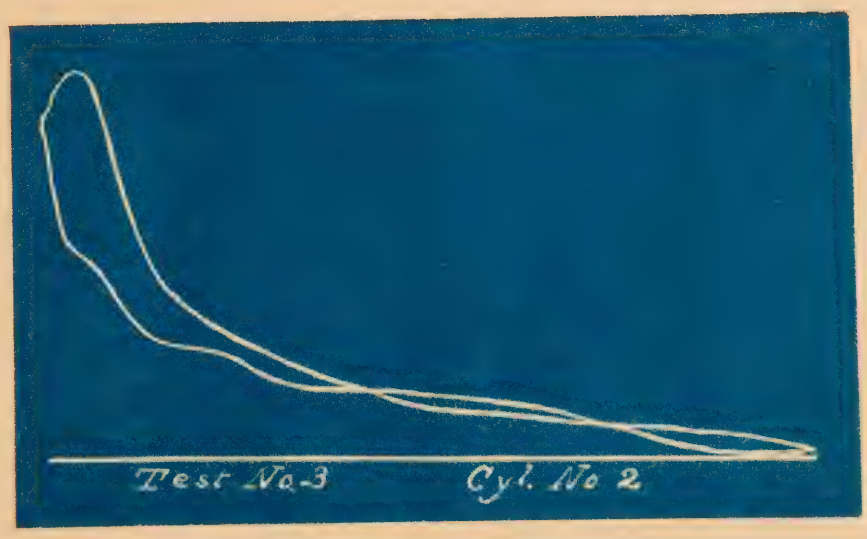
Time	Calorimeter Gauge lbs. per □"	Calorimeter lbs. water separator.	Steam Gauge lbs. per □"	Vacuum Gauge lbs. per □"	Shunt Amp. meter	Shunt Voltmeter	Temp. F Shunt Voltmeter	Terminal Voltmeter	Brake Amp. meter	Revolutions per minute	Time of last readings.
P.M.											
7-20	102.5	.045	100.0	0	4.15	84.5	78.0	108.0	0	371.0	7 20
7 30	105.0	.060	103.0	0	4.10	83.5	79.0	107.5	0	368.5	7 35
7-40	102.5	.085	100.5	0	4.20	85.0	80.0	107.5	0	366.0	7 47
7-50	102.0	.110	99.5	0	4.17	85.0	81.0	107.0	0	367.5	7-55
8-00	102.5	.145	101.0	0	4.36	89.0	81.5	110.0	0	368.5	8.05
8-10	102.0	.180	101.5	0	4.32	88.1	81.0	109.0	0	367.5	8-15
8-20	102.0	.205	102.5	0	4.30	88.2	81.0	109.0	0	368.5	—
8-30	102.5	.200	101.5	0	4.25	87.5	80.5	107.5	0	367.0	8 36
8-31.5	—	.030	—	0	—	—	—	—	—	—	—
8-40	105.0	.055	103.5	0	4.32	88.0	80.0	109.1	0	368.0	8-45
8-50	105.0	.085	102.0	0	4.31	87.5	80.0	109.0	0	368.0	—
			1015.0								
			101.5								

Sample Cards

from

Test No. 3. May 15th 1899.





Cards

Test No 3. May 15th 1899.

Time	← Cylinder No.1. Area □"	Length Inches	Cylinder No.2. Area □"	Length Inches. →
P.M.				
7 hrs 20 min	− 0.015	3.70	0.465	4.05
7 " 30 "	+ 0.044	3.73	0.460	4.03
7 " 40 "	+ 0.060	3.76	0.750	4.20
7 " 50 "	+ 0.030	3.75	0.535	4.14
8 " 00 "	+ 0.060	3.76	0.555	4.19
8 " 10 "	+ 0.040	3.74	0.550	3.99
8 " 20 "	+ 0.045	3.79	0.910	4.05
8 " 30 "	− 0.050	3.74	0.500	4.09
8 " 40 "	+ 0.040	3.78	0.960	4.04
8 " 50 "	+ 0.135	3.75	0.645	4.14
	+ 0.453			
	− 0.063			
	.390	37.53	6.330	40.92
	.039	3.753	.6330	4.092

Mean ordinate Cyl. No.1 = .0104" No. 2. 0.153 "

General Readings

Test No. 4 — May 30th. 1899.

Time	Calorimeter Gauge lbs. per □"	Calorimeter lbs. water separated	Steam Gauge lbs. per □"	Vacuum Gauge lbs. per □"	Shunt Ammeter	Shunt Voltmeter	Temp. Shunt Voltmeter	Terminal Voltmeter	Field Ammeter	Revolutions per minute	Time after readings
A.M.											
12-45	110	,000	100	0	4.25	82.0	82.	111.0	95.0	360.0	12-52
12-55	107	,030	97	0	4.30	82.0	82.	112.0	94.5	360.5	1-00
1-05	105	.070	94	0	4.40	85.0	82.	112.5	96.0	361.5	1-09
1-15	108	.105	95	0	4.40	85.0	82.	114.0	97.0	361.5	1-20
1-25	107	.140	95	0	4.40	85.0	82.	113.5	98.0	360.5	1-30
1-35	107	.175	95	0	4.30	84.0	82.	113.0	97.0	361.0	1-40
1-45	110	.215 .015	99	0	4.25	84.5	82.	113.0	97.0	362.0	1-49
1-55	112	.040	100	0	4.25	85.0	82.	113.0	98.0	363.0	1-59
2-05	110	.060	97	0	4.25	84.5	82.	112.0	96.5	361.5	2-10
2-15	107	.075	94	0	4.20	84.0	82.	112.0	96.0	361.0	2-19
2-25	107	.095	95	0	4.20	85.0	82.	112.0	96.0	362.0	2-29
2-35	107	.115	95	0	4.30	87.0	82.	113.0	96.5	362.0	2-40
2-45	112	.140	99	0	4.30	87.0	82.	114.0	98.0	362.0	2-49
	1409		1255					1464.0	1255	4698.5	
	108.38		96.54					112.61	96.57	361.42	

Readings - Water.

Test No. 4. May 30th 1899.

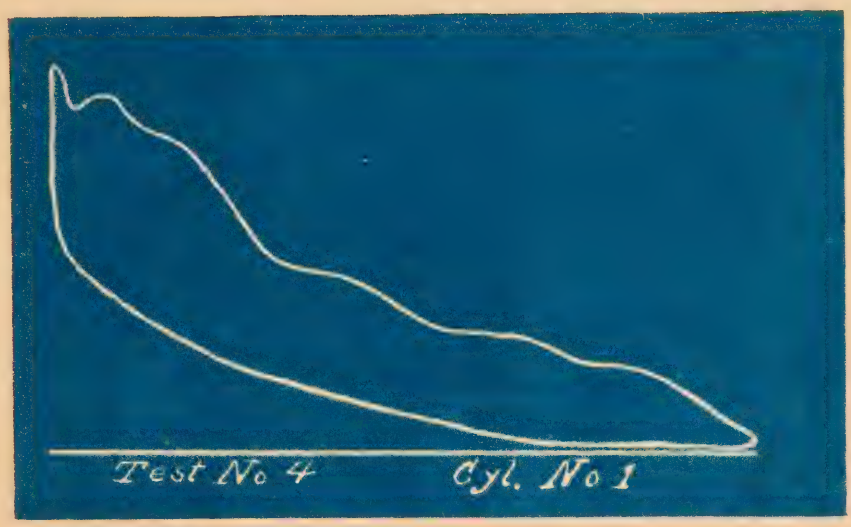
Time.	Weight lbs.	Weight Empty lbs.	Net. wt. of condensed steam lbs.
A.M.			
12-45	142.5	142.5	0.
12-55	258.5		
1-05	377.0		
1-15	494.0		
1-25	613.5	142.5	471.0
1-30	151.0	151.0	0.
1-35	269.0		
1-45	389.5		
1-55	509.0		
2-05	627.0	151.0	476.0
2-10	143.5	143.5	0
2-15	259.0		
2-25	376.5		
2-35	492.5		
2-45	610.5	143.5	467.0

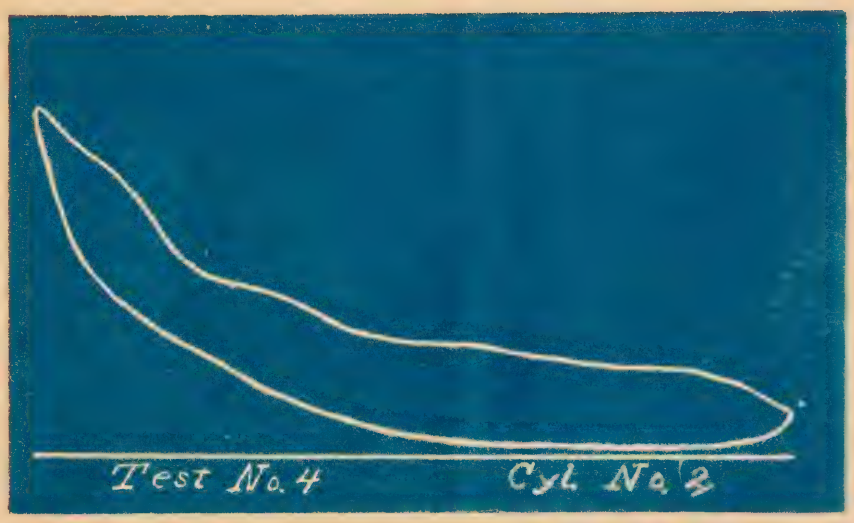
707 lbs steam condensed per hour.

Sample Cards

from

Test No. 4. May 30th 1877





Cards

Test No. 4. May 30th 1899.

Time	Cylinder No 1 Area □"	Length Inches.	Cylinder No 2. Area □"	Length Inches.
A.M.				
12-45	2.155	3.65	1.750	3.86
12-55	2.140	3.65	1.690	3.89
1-05	2.160	3.67	1.775	3.95
1-15	2.160	3.67	1.750	3.96
1-25	2.160	3.67	1.690	3.93
1-35	2.160	3.69	1.745	3.95
1-45	2.140	3.73	1.705	3.98
1-55	2.230	3.71	1.705	3.96
2-05	2.155	3.67	1.745	3.98
2-15	2.165	3.68	1.760	3.89
2-25	2.135	3.67	1.725	3.92
2-35	2.230	3.66	1.715	3.95
2-45	2.205	3.66	1.710	3.99
	28.195	47.78	22.510	51.12
	2.1688	3.675	1.7315	3.932

Mean ordinate No1. 05901 No. 2. .4530

General Readings

Test No. 5. May 31st 1899.

Time.	Calorimeter Gauge lbs per □"	Calorimeter lbs water separated.	Steam Gauge lbs per □"	Vacuum Gauge lbs per □"	Shunt Ammeter	Shunt Voltmeter	Jenny Shunt Voltmeter	Terminal Voltmeter.	Board Ammeter	Revolutions per minute	Weston Ammeter
A.M.											
12-50	115.0	.030	98.5	0	4.31	86.0	85.5	111.5	131.0	358.5	132.0
1-00	110.0	.045	96.0	0	4.39	88.0	85.5	112.5	133.0	359.5	135.0
1-10	110.0	.060	95.5	0	4.39	88.5	—	113.0	131.0	—	133.0
1-20	110.0	.075	94.5	0	4.35	89.0	85.8	112.5	132.0	361.0	135.0
1-30	110.0	.095	96.0	0	4.38	89.5	86.0	114.0	132.0	363.0	136.0
1-40	115.0	.110	99.5	0	4.38	89.8	86.0	114.0	131.0	362.0	135.0
1-50	112.5	.130	97.5	0	4.32	89.5	86.0	113.5	131.5	361.0	136.0
2-00	110.0	.150	96.0	0	4.28	88.0	86.0	112.5	131.0	360.5	135.0
2-10	115.0	.175	102.0	0	4.30	90.0	85.5	114.0	131.0	362.5	136.0
2-12	—	.040	—	—	—	—	—	—	—	—	—
2-20	115.0	.055	101.0	0	4.28	89.5	85.5	113.5	131.0	364.0	137.0
2-30	112.5	.075	99.0	0	4.20	89.3	85.5	112.8	129.5	361.5	135.0
2-40	115.0	.095	101.0	0	4.23	90.0	85.5	113.5	129.5	361.5	138.0
2-50	110.0	.110	97.5	0	4.20	89.0	85.0	112.0	127.5	362.5	135.0
	1460.0		1274.1					1469.3	1703.0	4837.5	
	112.3		98.01					113.02	131.0	361.46	

Readings - Water.

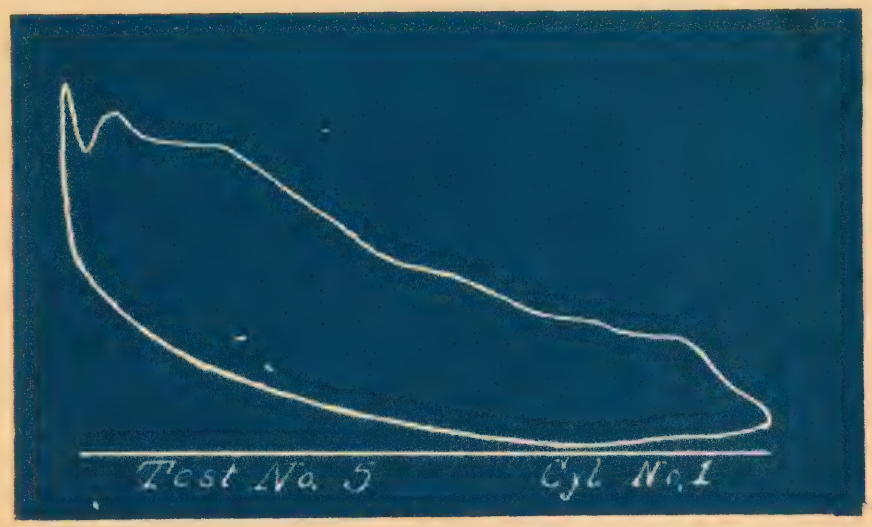
Test No. 5. May 31st 1899.

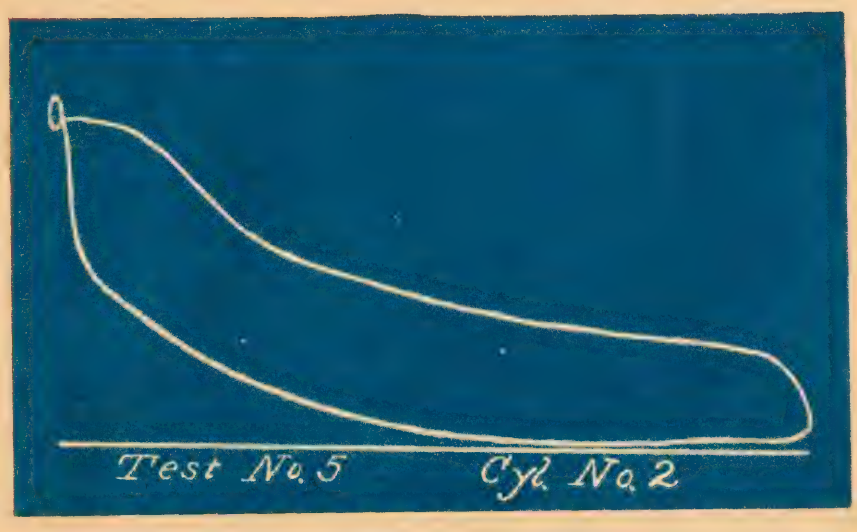
Time	Weight lbs.	Weight Empty lbs.	Nt. wt. of condensed steam lbs.
A. M			
12-50	141.0	141.0	0
1-00	295.0		
1-10	444.5		
1-20	590.5	141.0	449.5
1-30	295.0		
1-40	443.0		
1-50	590.0	148.0	442.0
2-00	292.0		
2-10	439.0		
2-20	585.5	146.0	439.5
2-30	291.5		
2-40	433.5		
2-50	575.0	144.0	431.0
			1762.0

881 lbs steam condensed. per hr.

Sample Cards.

Test No. 5. May 31st 1897.





Cards

Test No. 5. May 31st 1899.

Time	← Cylinder No. 1 → Area □"	Length Inches.	← Cylinder No 2. → Area □"	Length. Inches
A. M.				
12-50	2.980	3.65	2.630	3.870
1-00	3.030	3.67	2.550	3.89
1-10	3.005	3.67	2.580	3.90
1-20	2.985	3.68	2.500	3.90
1 30	3.025	3.71	2.545	3.92
1-40	3.005	3.67	2.540	3.93
1-50	3.020	3.69	2.560	3.89
2-00	2.900	3.67	2.565	3.94
2-10	2.985	3.67	2.495	4.00
2-20	2.915	3.68	2.495	3.93
2 30	2.935	3.70	2.455	3.96
2-40	2.930	3.69	2.490	4.04
2-50	2.980	3.71	2.505	4.02
	38.695	47.86	32.690	51.19
	2.977	3.677	2.515	3.937

Mean ordinate Cyl. No 1. 0.815" No.2. 0.636"

Results.

Test. No. 1.

5-11-'99

I.H.P. — M.E.P Cyl No 1. = .225" x 49.4 = 11.115 lbs.

" " " " " 2 = .291 x 52.23 = 15.198 "

26.313 "

Revs per min = 368.4

Length of stroke = 7."

Area piston = 44.178 sq inches

$$I.H.P. = \frac{26.313}{33000} \times \frac{7}{12} \times 44.18 \times 368.4 = 7.75$$

Elec. H.P. Mean Volts 110.76 Corrected value 109.7

" Amperes 32.83 " " 32.5

$$= \frac{109.7 \times 32.5}{746} = 4.78$$

$$\text{Commercial Efficiency} = \frac{\text{Elec H.P.}}{\text{I.H.P.}} = \frac{4.78}{7.75} = 61.54\%$$

$$\text{Water per Kilo-watt Hour} = \frac{463.25 \times 1000}{109.7 \times 32.5} = 129.94$$

Calorimeter Average Steam Press 92.46 Corr. 89.0 lbs.

Steam discharged in 10 min = 4.16 lbs.

Water Separated " " " = .0201

Total Steam & Water in 10 min. 4.1801

Percentage Moisture $\frac{.0201}{4.1801} = .48\%$

Test No. 2. 5-15-'99.

I.H.P. M.E.P. Cyl No 1. = .376 x 49.4 = 18.574

" " " " 2 .289 x 52.23 = 15.094

33.668

I.H.P. $33.668 \times \frac{1}{33000} \times \frac{14.178}{12} \times 362.7$ = 9.537

Elec. H.P. Mean Volts 111.5 Corrected = 110.5

" Amperes 64.08 " = 63.6

Elec H.P. = $\frac{110.5 \times 63.6}{746}$ = 9.42

Commercial Effic = $\frac{9.42}{9.537}$ = 98.9 o/o.

Water per Kilo-watt Hour = $\frac{615 \times 1000}{63.6 \times 110.5}$ = 87.59

Calorimeter Average Steam Press 95.58 Corr. 94.5

Steam disch in 10 min = 4.375 lbs.

Water separated " " = .025

Total steam & water = 4.400.

Percentage Moisture = $\frac{.025}{4.40}$ = 0.56 o/o.

Test No. 3

I.H.P. M.E.P. Cyl No 1 = .0104 × 49.4 = 0.5137

" " " " 2 = .1546 × 52.23 = 8.0956

8.609

$$= \frac{8.609 \times 7 \times 44.18 \times 368}{12 \times 33000} = 2.4715$$

Elec. H.P = 0.

Commercial Efficiency = 0.

Water per Kilo-watt Hour = ——

Calorimeter.

Steam Press. 101.3 Corrected = 99.0 lbs

Steam discharged in 10 min. = 4.562

Water separated in " " = .023

Total Steam & Water " " = 4.585.

Percentage Moisture = $\frac{.023}{4.585} = 0.63\%$

Test. No. 4 — 5 30- '99

I.H.P M.E.P. Cyl. No. 1 = .59" × 49.4 = 29.146

" " 2 = .453" × 52.23 = 23.760

52.906

$= \frac{52.91 \times 7 \times 44.18 \times 361.42}{12 \times 33000} = 14.935$ H.P.

Elec. H.P. Mean Volts 112.61 Corrected = 111.7

" Amperes 96.57 " 96.0

$= \frac{112.61 \times 96.57}{746} = 14.37$ H.P.

Commercial Efficiency $\frac{14.37}{14.935} = 96.2$ o/o

Water per. Kilo-watt Hour $= \frac{707 \times 1000}{112.61 \times 96.57} = 65.88$ lbs

Calorimeter - Steam Press 96.54 Corrected 94.5

Steam discharged in 10 min = 4.375

Water collected " " = .028

Total Steam & Water " " = 4.403

Percentage Moisture - $\frac{.028}{4.403} = 0.63$ o/o

Test No. 5

5-31-99.

I.H.P. – M.E.P. Cyl. No1. .815 x 49.4 = 40.261

" " 2 .436 x 32.23 = 33.218

73.479

$= \frac{73.479 \times 7 \times 74.18 \times 361.5}{12 \times 33000} = 20.75$

Elec H.P. Mean Volts 113.02 Corrected = 112.0

" Amperes 131.0 " 130.0

$= \frac{112.0 \times 130.0}{746} = 19.57.$

Commercial Efficiency $= \frac{19.57}{20.75} = 94.06\%$.

Water per Kilo-watt Hour $= \frac{881 \times 1000}{112 \times 130} = 60.51$ lbs.

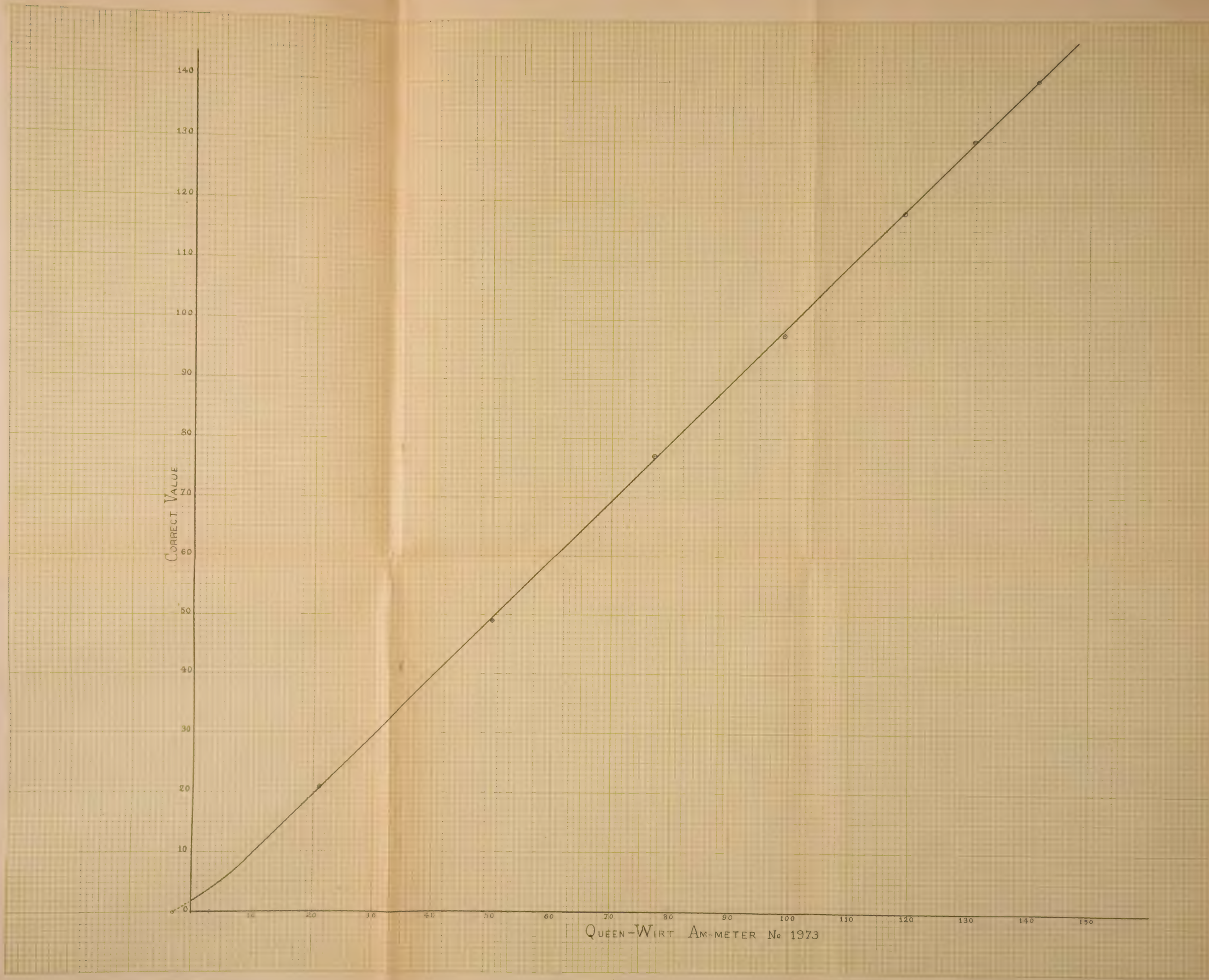
Calorimeter Steam Press 98.01 Corrected 96.0

Steam discharged in 10 min 4.44

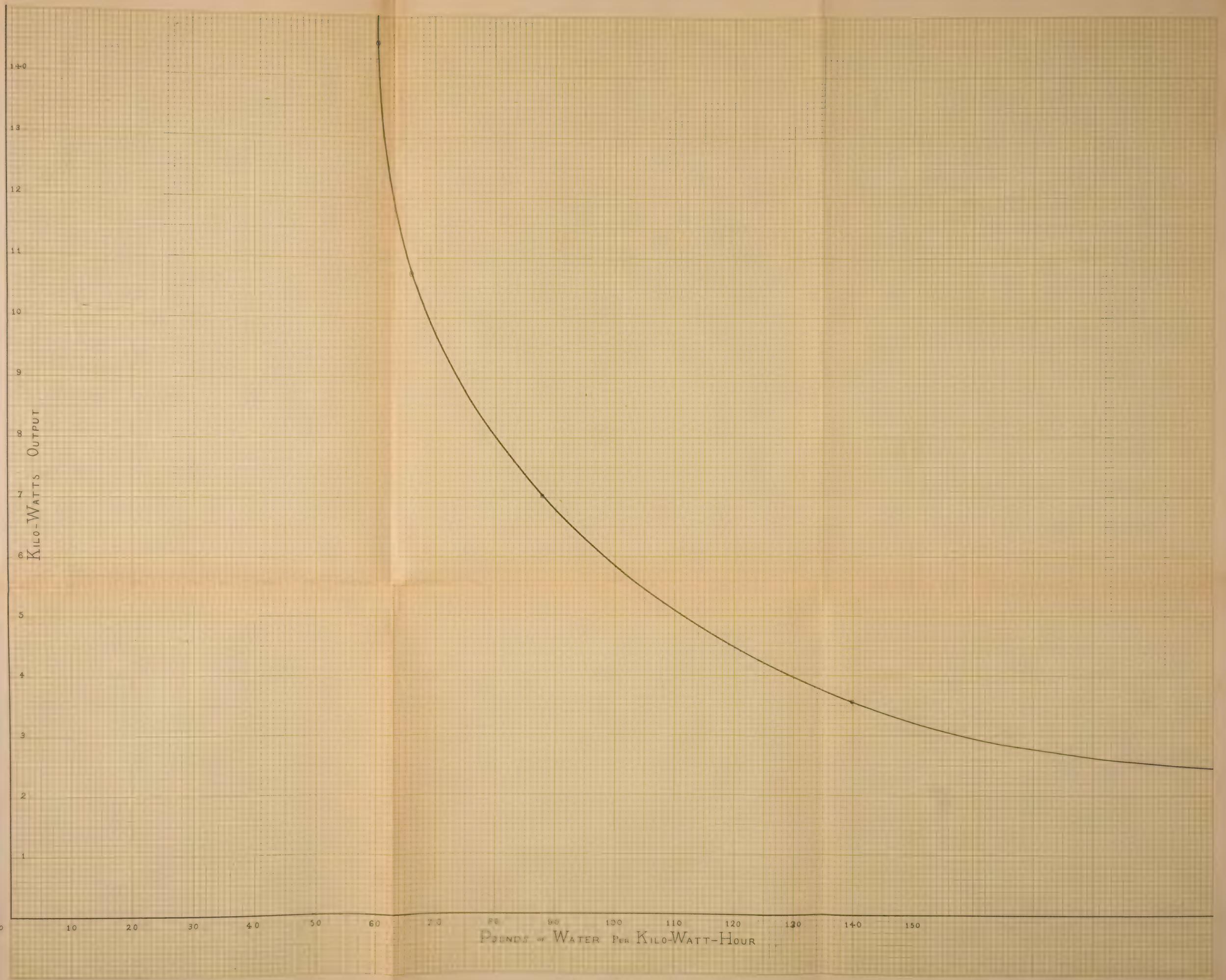
Water collected " " " .0185

Total Steam & Water. 4.4585

Percentage Moisture $= \frac{.0185}{4.4585} = 0.415\%$.



Queen-Wirt Am-meter No 1973


Kilo-Watts Output
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Pounds of Water Per Kilo-Watt-Hour

Indicator Rig

Half Size

Fig 1

W.C.K

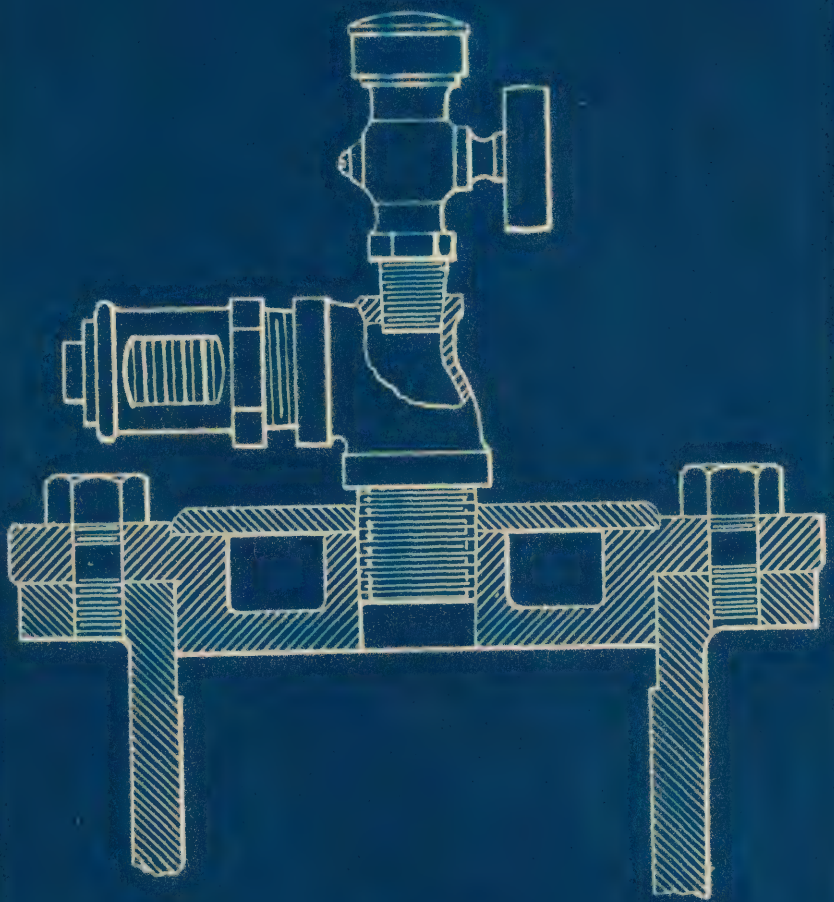


Fig 2

W.C.S. 4/11

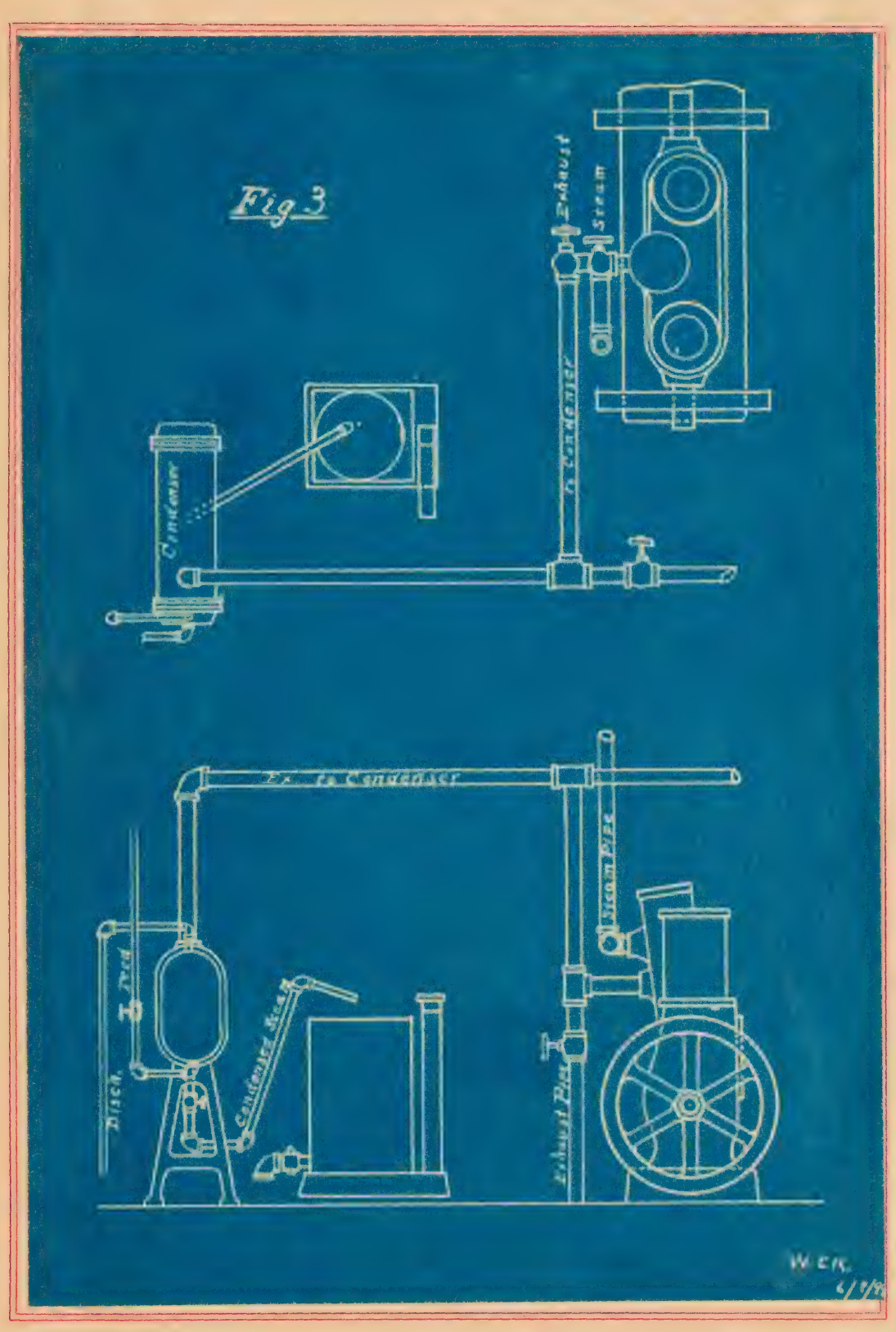
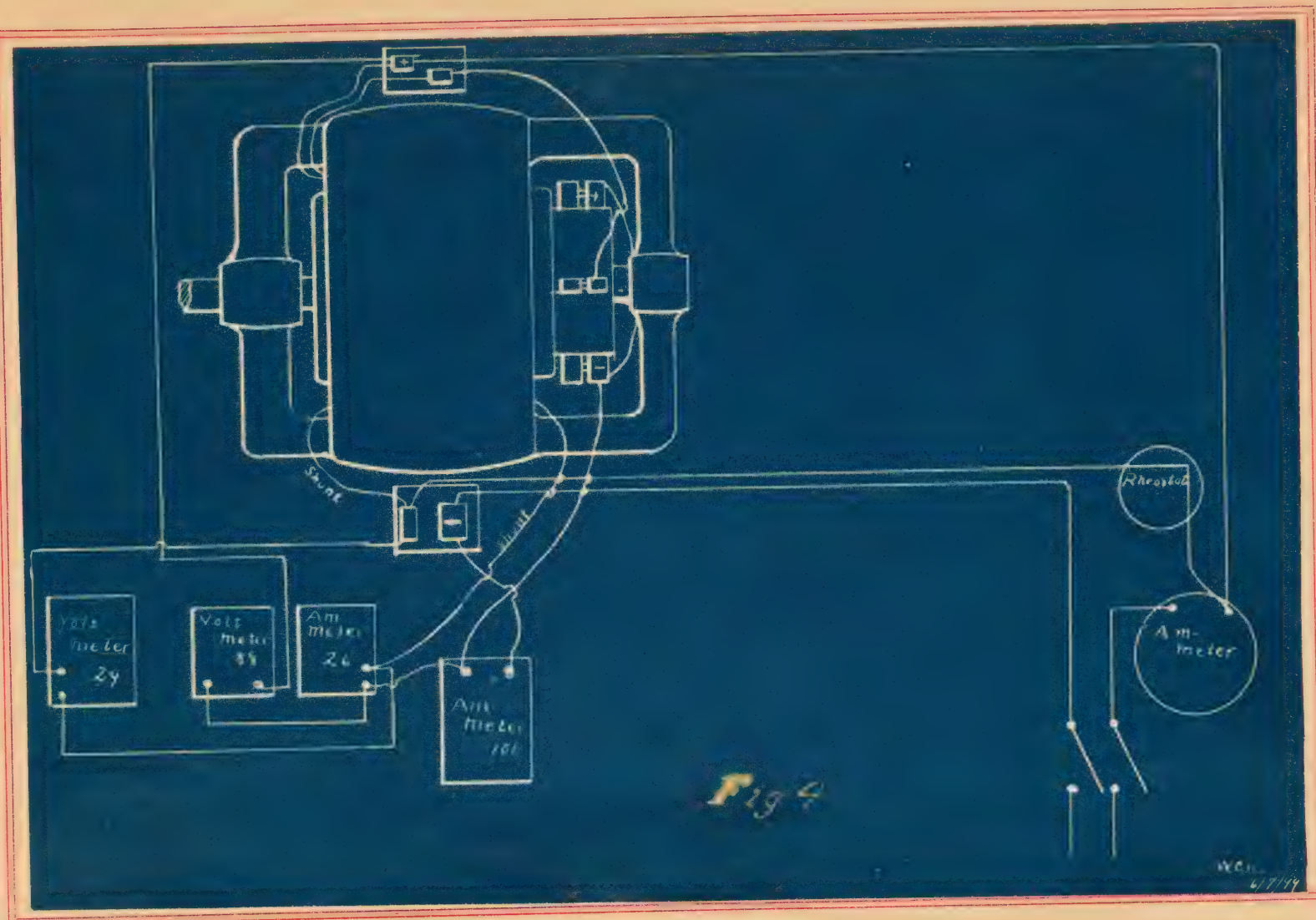


Fig 3
Exhaust
Steam
Condenser
Condenser
Exhaust Pipe
Steam Pipe
Condenser Head
Discharge
Feed
W.C.R.
6/3/98


Shunt
Rheostat
Volt meter 24
Volt meter 24
Am meter 24
Am meter 100
Am-meter
Fig 4
W.C.L.
6/7/14

3 1198 03073 3047
N/1198/03073/3047X

3 1198 03073 3047
N/1198/03073/3047X